TEVATRON STUDY REPORT: LOSSES VS CHROMATICITY 11/26/02

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Abstract

During the end-of-store study on November 26, 2002, we measured the proton and pbar beam lifetimes and loss rates at 980 GeV as a function of the vertical and horizontal chromaticity. Unlike in previous studies, the two chromaticities were lowered simultaneously. There was no noticable change in the beam lifetime or in the loss rate over about 10 units of chromaticity. Only a gradual 10% increase was seen in the p-bar horizontal Schottky power until an abrupt quench occurred at a cromaticity setting 10 units lower than nominal. This quench appeared to have been caused by the loss of the pbar beam. T. Sen has explained this pbar instability by the large chromaticity difference between protons and antiprotons, which arises from the long-range collisions.

1 SEQUENCE OF EVENTS

At 22:14 we recorded initial settings of chromaticities (these settings were Ch=64 and Cv=71 on page C49) and set up fast time plots including Schottky power (SHPWR, SVPWR), and loss rates for protons and pbars as detected by CDF and D0 (LOSTP, LOSTPB, D0AHTL, D0PHTL). We used the page T55 to change the chromaticities and to read the values during the study.
From 22:42 on, we lowered the horizontal and vertical chromaticities in steps of –1 for both planes, at a speed of roughly 1.5 minutes per step. The Tevatron quenched at about 22:58, immediately after reaching our final setting of –10 units change in both planes. The loss pattern indicated that the quench was caused by the pbars, since there were large and growing losses at the pbar collimators F48 and D17 (this conjecture is based on informations by D. Still and the operators).
We here note that in previous MDs, the chromaticity had been lowered much further, in one plane at a time, without inducing a quench., that the proton chromaticity at the starting point of the present scan was measured one week earlier, on 11/17.02, and that the calculated pbar chromaticities strongly differ from those of the protons due to parasitic beam-beam collisions.

2 RESULTS

Figure 1 shows the change in the sextupole strengths which resulted from changing the two chromaticities in steps of –1 by up to -10 units. The associated loss rates for protons and antiprotons are displayed in Fig. 2, and the beam intensities in Fig. 3. The chromaticity change has no effect, neither on the losses nor directly on the intensity. Figure 4 presents the Schottky power during the same time span. The vertical Schottky power is equally flat, but the horizontal power exhibits a slow gradual increase, as the chromaticity decreases.

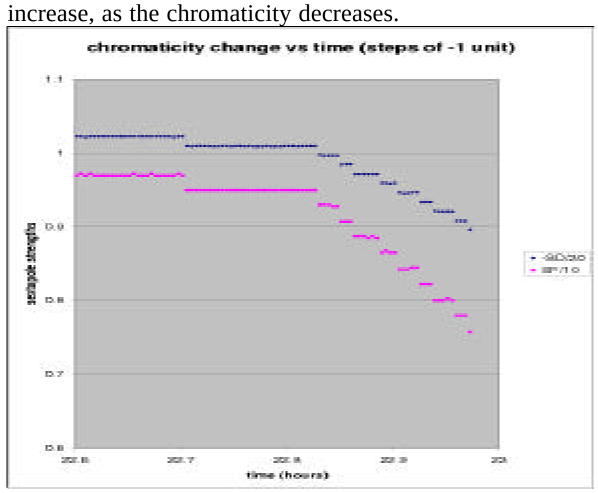

Figure 1: Sextupole strengths vs. time, as the horizontal and vertical chromaticities were lowered in steps of –1, by a total of –10 units.

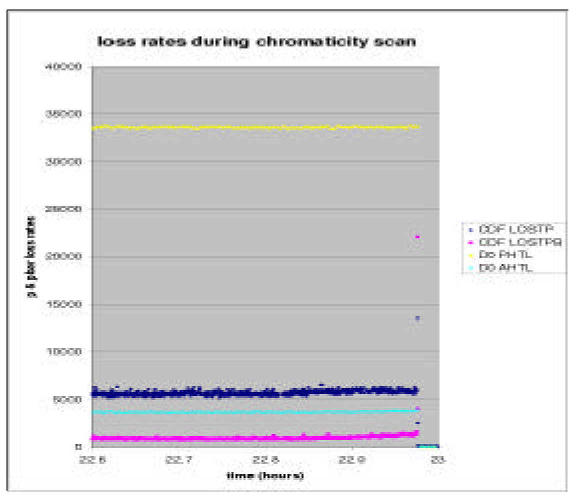

Figure2: Proton and pbar loss rates in CDF and D0 as a function of time during the chromaticity scan.

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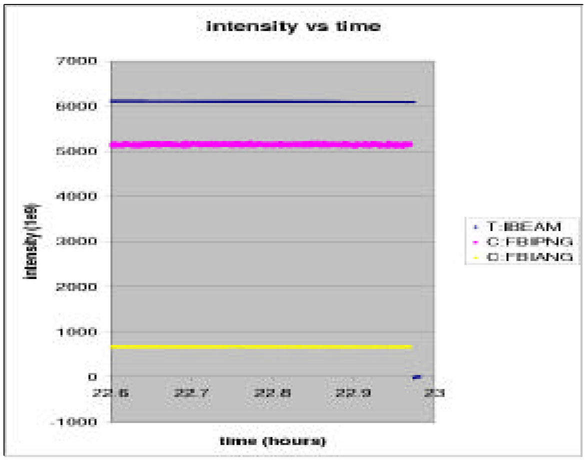

Figure3: Total, proton and pbar intensities as a function of time during the chromaticity scan.

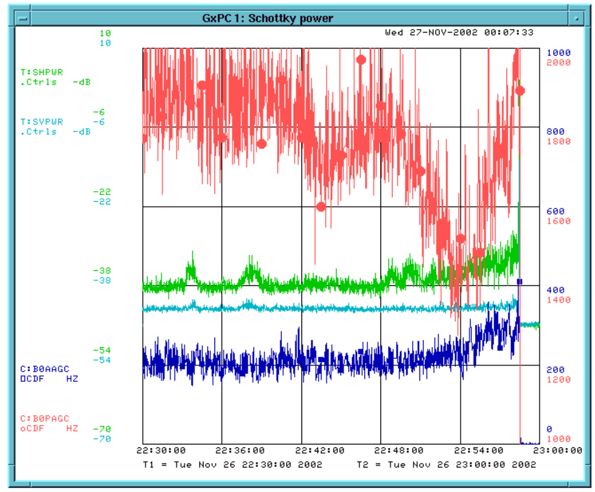

Figure 5: Schottky power (centre) and abort gap loss rates for protons and pbars (top and bottom curves) as a function of time during the chromaticity scan.

The sudden quench at –10 units in chromaticity terminated this experiment. The chromaticity change did have some effect on the abort-gap losses. Figure 5 shows that after lowering the chromaticity in both planes by 5 units, the proton abort gap losses decreased. They went back up just prior to the quench, while the pbar loss rate in the abort gap grew continually.

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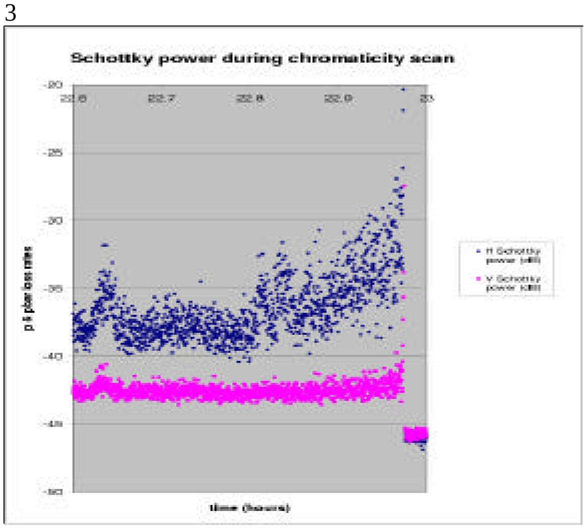

Figure 4: H and vertical proton Schottky power as a function of time during the chromaticity scan.

Figures 6 and 7 show loss rates near the pbar collimators F48 and D17, in the two seconds before the quench. The losses in both locations increase by three or four orders of magnitude.

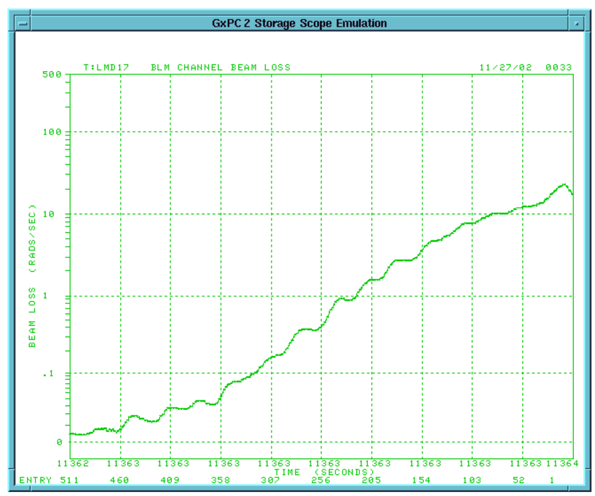

Figure 6: Loss rate at D17 in the 2 seconds before the quench.

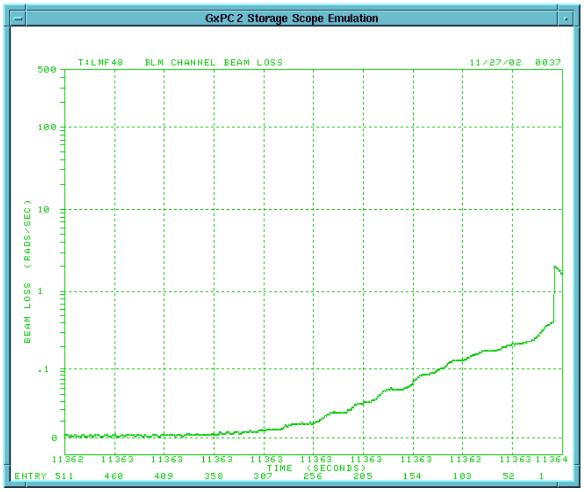

Figure 7: Loss rate at F48 in the two seconds before the quench.

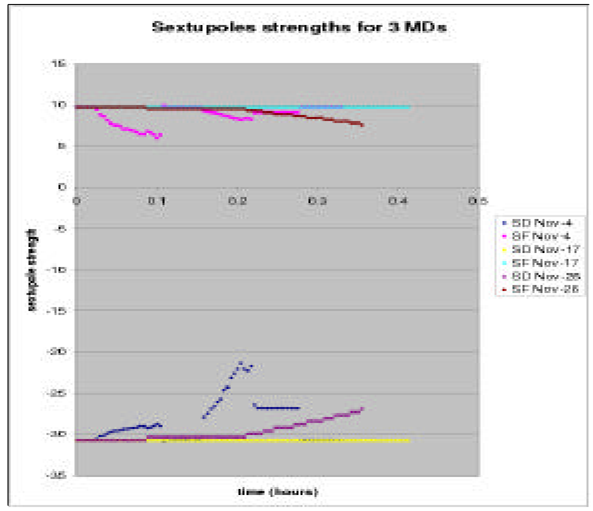

Figure 7: Values of sextupole strengths during X.L.Zhang's study on November 4, during pbar removal study on November 17, and during the present study (11/26).

3 INTERPRETATION

The following points are worth mentioning:

1) The quench had the signature of a pbar-induced quench.
2) On November 4, X.L. Zhang had successfully scanned both Ch and Cv by –24 and –20 units, respectively, i.e., over a much wider range. At that time, a quench occurred at –21 units in Cv.
3) During the pbar removal study on November 17, the proton chromaticities were measured to be Ch=13 and Cv=16 at the end of the store.
4) According to a calculation by Tanaji Sen, the 0-amplitude chromaticities of the pbars are lower by –10 and –1 units than those of the protons, in the horizontal and vertical plane, respectively. (At 3σ amplitude in x and y, the differences are –6 and –3, for $6\sigma^2$ normalized emittances of 20 μm.) These numbers apply to the typical intensity of $2.7\text{x}10^{11}$ protons per bunch at the start of a store. They must be scaled with the actual proton intensity, in our case about $1.4\text{x}10^{11}$ per bunch, or about half the 'nominal' value.
5) At injection we found that the chromaticities on the pbar helix were about 4 units lower than those on the proton helix [1]. Part of this difference may still be present at top energy.

If we combine 3) and 4), we can estimate that in the course of this study the actual proton chromaticities were reduced from Ch=13 and Cv=16 to Ch=3, Cv=6, whereas the pbar chromaticities were shifted from Ch=3, and Cv=15 to Ch=–2 and Cv=5. The predicted negative horizontal chromaticity would explain why the quench was caused by the pbars, and why the horizontal Schottky power increased in Fig. 4.

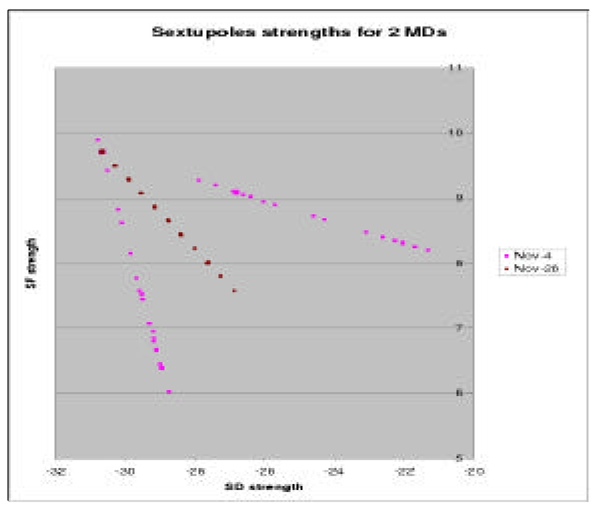

Figure 8: Paths of sextupole variation during X.L.Zhang's study on November 4 (changes to either horizontal or vertical chromaticity), and during the present study (11/26).

Figures 7 and 8 compare the sextupole strengths in the present experiment with those on November 4 and November 17. The starting values were the same in all three cases, which in particular confirms that we can assume the same proton chromaticities as measured on November 17 for the initial point of the scan. Figure 8 illustrates that at the end of the scan the sextupole strengths were sufficiently different from those probed on November 4, so that there is no contradiction in the positions of the respective quenches.

Finally, found some circumstantial evidence that the strengths of the feed-down sextupoles were not exactly the same for the two studies, namely the currents of S5F1A-S5D3A were about 50% different: 4.2 or 4.3 A on November 4, and 6.7 A on both November 17 and November 26. It is not clear why these settings differed, and whether this would have an impact on the pbar beam stability.

4 CONCLUSIONS

Proton and pbar losses at 980 GeV are almost independent of the chromaticity, at least at this working point (proton tunes Qh=0.5888, Qv=0.5770, pbar-A24 tunes Qh=0.5897, Qv=0.5741; see pbar removal study on 11/17). Hence there is no clear advantage in decreasing the chromaticity, which can only drive the beam unstable, but does not seem to improve the beam lifetime. However, a possible effect on the transverse emittance growth time has not been examined, and the observed decrease in the proton abort-gap losses for lower chromaticities looks promising. The fact that the pbars caused the quench when the chromaticity was lowered and the increase in the horizontal Schottky power are both consistent with the predicted large difference in the horizontal chromaticity of protons and pbars (at nominal intensity the horizontal pbar chromaticity is up to -10 units lower, according to T. Sen). Differential adjustments of the chromaticity for the two beams, at least in the horizontal plane, might be a worthwhile option to consider for the future. This could be achieved by means of octupoles at places with nonzero dispersion where the beams are horizontally separated.

5 ACKNOWLEDGEMENTS

Many thanks to T. Asher for his help during this study, to T. Sen for pointing out the large difference between proton and pbar chromaticities as an explanation for the quench, to D. Still for confirming that the beam loss was caused by the pbars, and to V. Shiltsev for his continued encouragement and support.

REFERENCES

[1] J. Annala, V. Shiltsev, D. Still, C.Y. Tan, X.L. Zhang, F. Zimmermann, 'Tevatron Study Report: Measuring Pbar Tunes with Tan's-System, Beam Separation, and Pbar Removal 12/03/02'